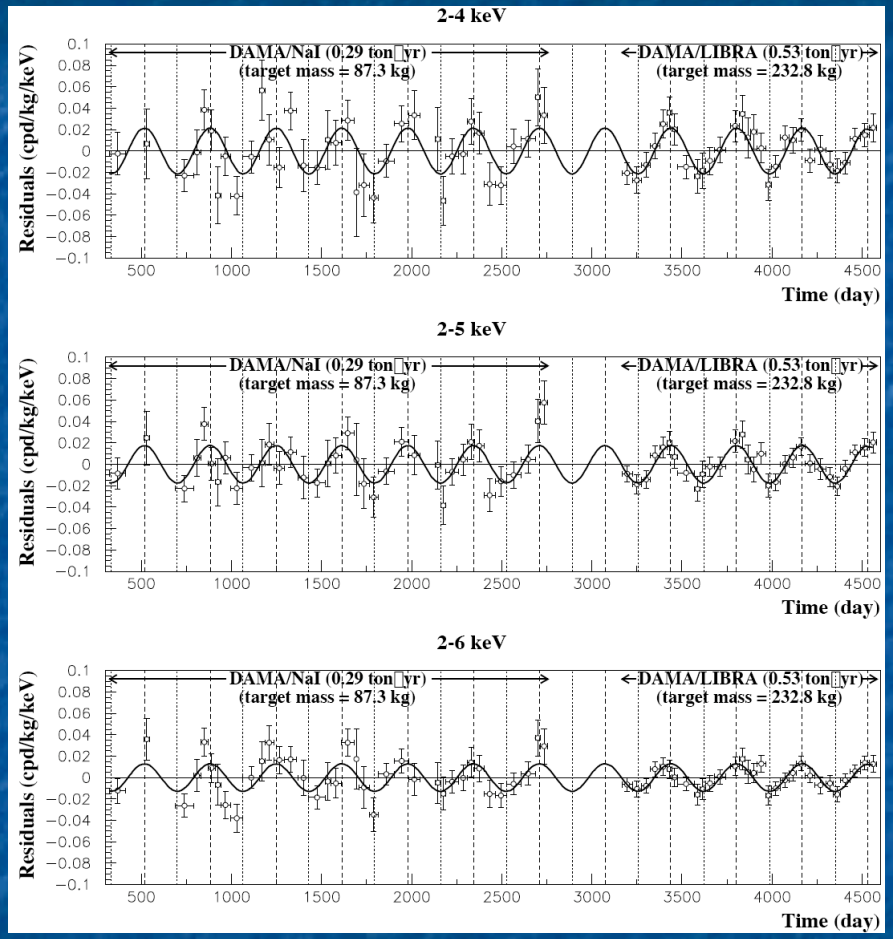
Inelastic Dark Matter

Dave Tucker-Smith
Williams College

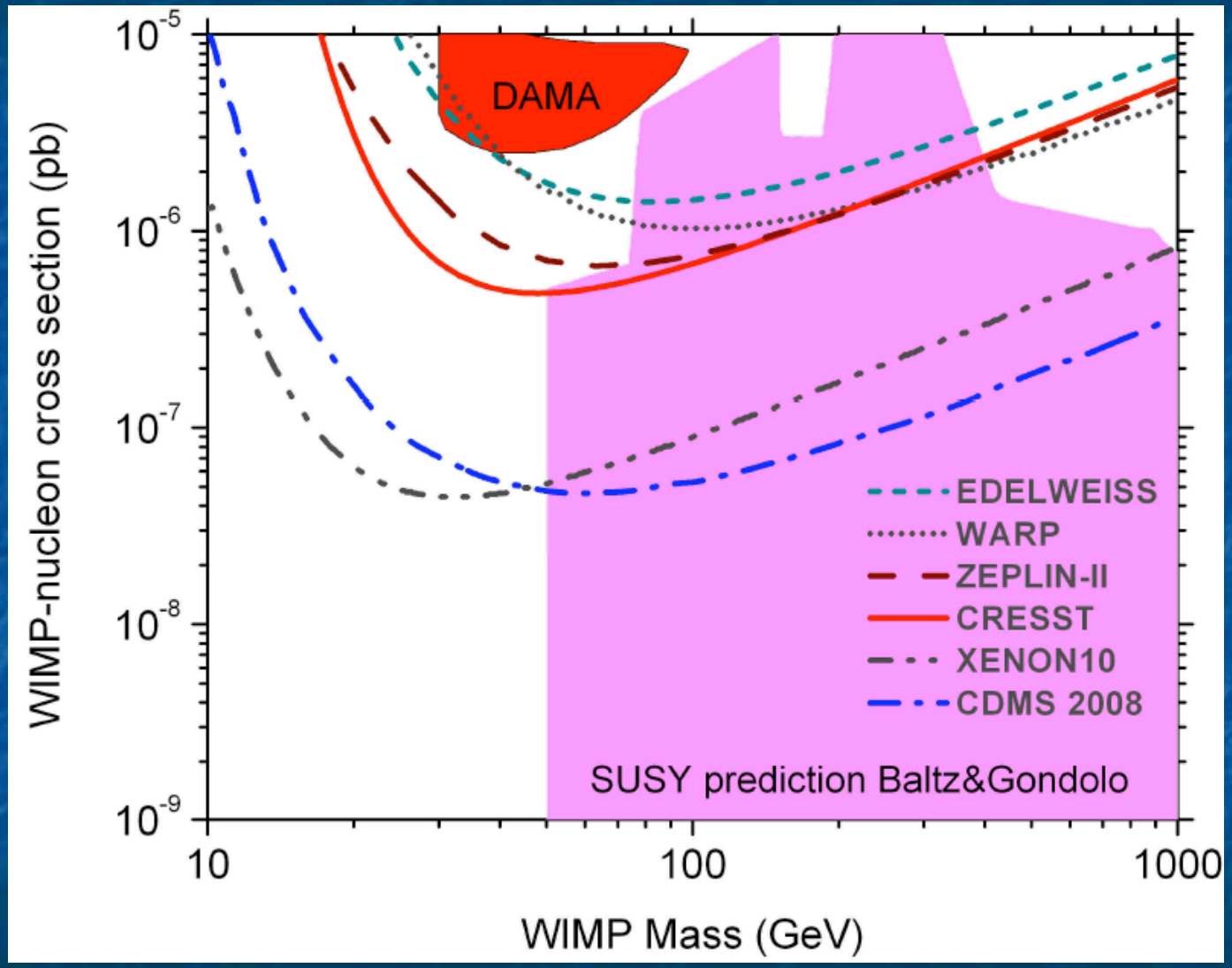
arXiv:0807.2250
with S. Chang, G. Kribs, and N. Weiner

Has DAMA detected dark matter?



	A (cpd/kg/keV)	$T = \frac{2\pi}{\omega}$ (yr)	t_0 (day)	C.L.
DAMA/NaI				
(2–4) keV	0.0252 ± 0.0050	1.01 ± 0.02	125 ± 30	5.0σ
(2–5) keV	0.0215 ± 0.0039	1.01 ± 0.02	140 ± 30	5.5σ
(2–6) keV	0.0200 ± 0.0032	1.00 ± 0.01	140 ± 22	6.3σ
DAMA/LIBRA				
(2–4) keV	0.0213 ± 0.0032	0.997 ± 0.002	139 ± 10	6.7σ
(2–5) keV	0.0165 ± 0.0024	0.998 ± 0.002	143 ± 9	6.9σ
(2–6) keV	0.0107 ± 0.0019	0.998 ± 0.003	144 ± 11	5.6σ
DAMA/NaI+ DAMA/LIBRA				
(2–4) keV	0.0223 ± 0.0027	0.996 ± 0.002	138 ± 7	8.3σ
(2–5) keV	0.0178 ± 0.0020	0.998 ± 0.002	145 ± 7	8.9σ
(2–6) keV	0.0131 ± 0.0016	0.998 ± 0.003	144 ± 8	8.2σ

DAMA Collaboration (R. Bernabei *et al.*), **Eur.Phys.J.C56:333-355,2008**.



G. Angloher et al. (CRESST), arXiv:0809.1829

D. Tucker-Smith, BF2008

How to reconcile with other experiments?

- Constraints from CDMS II, XENON10, etc. seem to rule out a standard WIMP with SI interactions as interpretation of DAMA data.

- If the DAMA signal is from dark matter . . .
  - how does the dark matter evade detection elsewhere?
  - what other signatures can we expect?

Consequences of inelastic dark matter

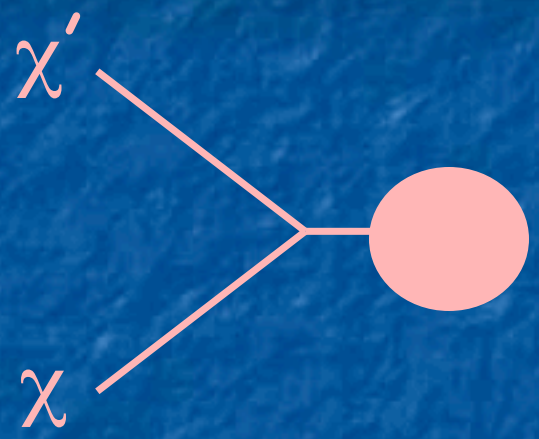
DTS, N. Weiner

- Heavier targets are favored over lighter ones (e.g. I over Ge).
- Annual modulation is enhanced relative to average signal.
- Energy spectrum is changed dramatically, with low-energy events suppressed.

Inelastic dark matter

$$M_{\chi'} = M_{\chi} + \delta$$

$$\delta \sim 100 \text{ keV}$$

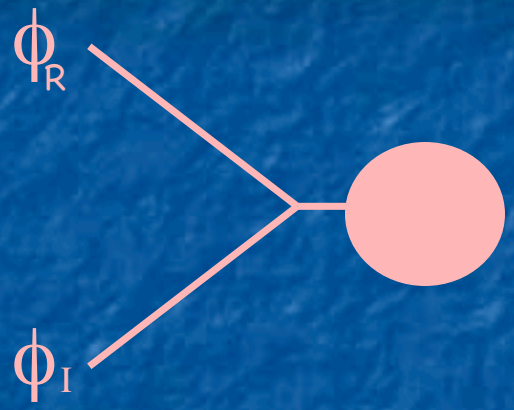


- Elastic scattering, $\chi N \rightarrow \chi N$, is either absent or suppressed.

Inelastic scattering , $\chi N \rightarrow \chi' N$, dominates.

Kinematically allowed only if velocity is large enough: $\beta > \sqrt{2\delta/\mu}$

Inelastic scalars



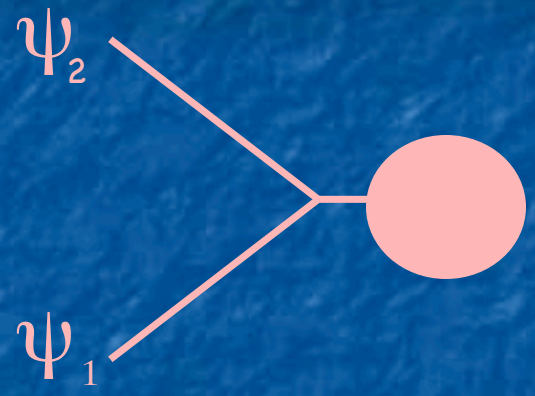
Real and imaginary parts of a complex scalar are kept degenerate by U(1) symmetry.

If the U(1) is broken by a small amount, the degeneracy is lifted.

Example: sneutrino with lepton number violating mass squared term. Coupling of Z to real and imaginary parts is off-diagonal.

Hall, Moroi, Murayama

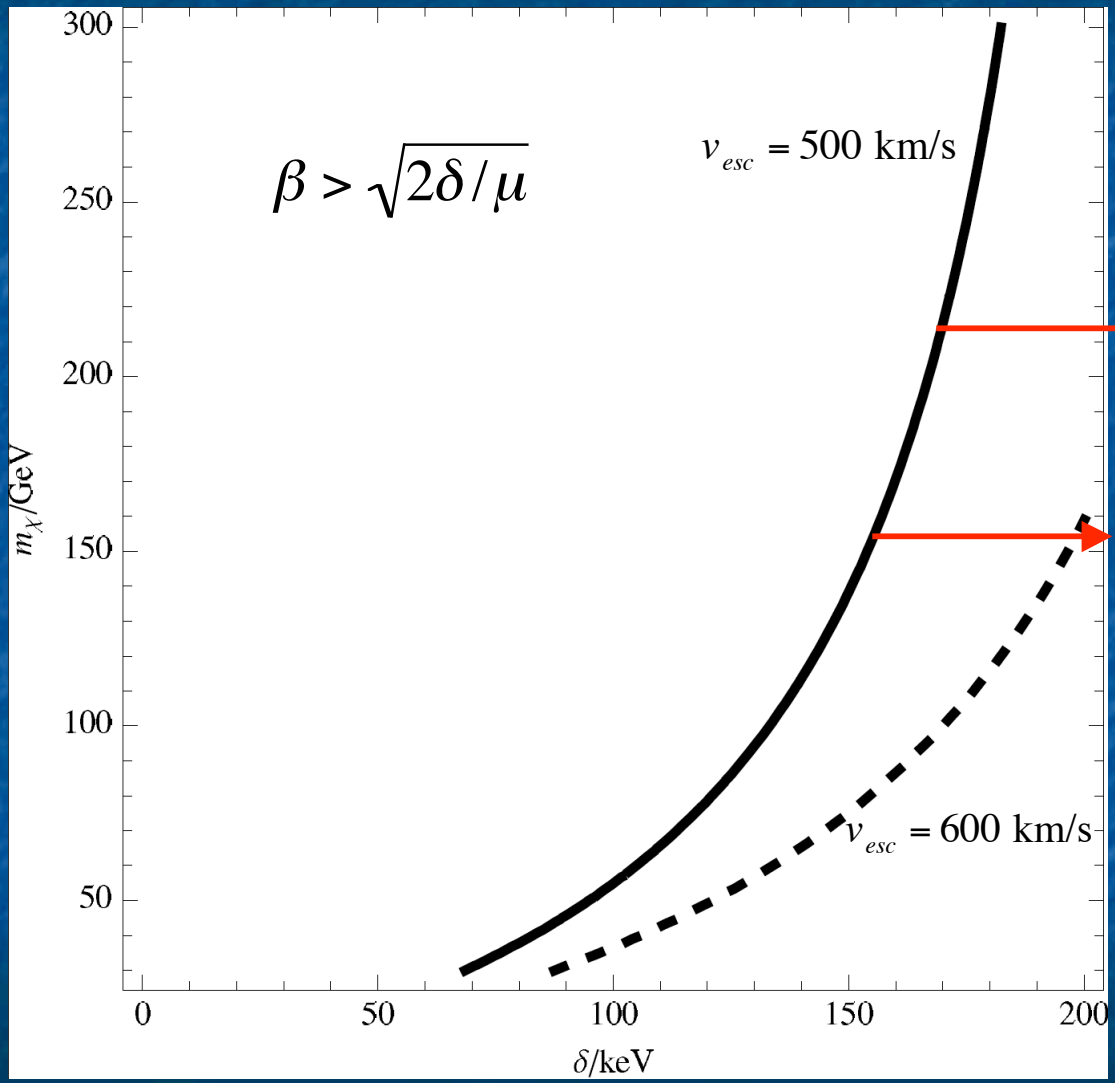
Inelastic fermions



If heavy Dirac neutrino has small Majorana mass, couplings of left- and right-handed components to Z boson is off-diagonal

Another example: pseudo-Dirac neutralinos in a SUSY model with extended R symmetry. Kribs, Poppitz, Weiner

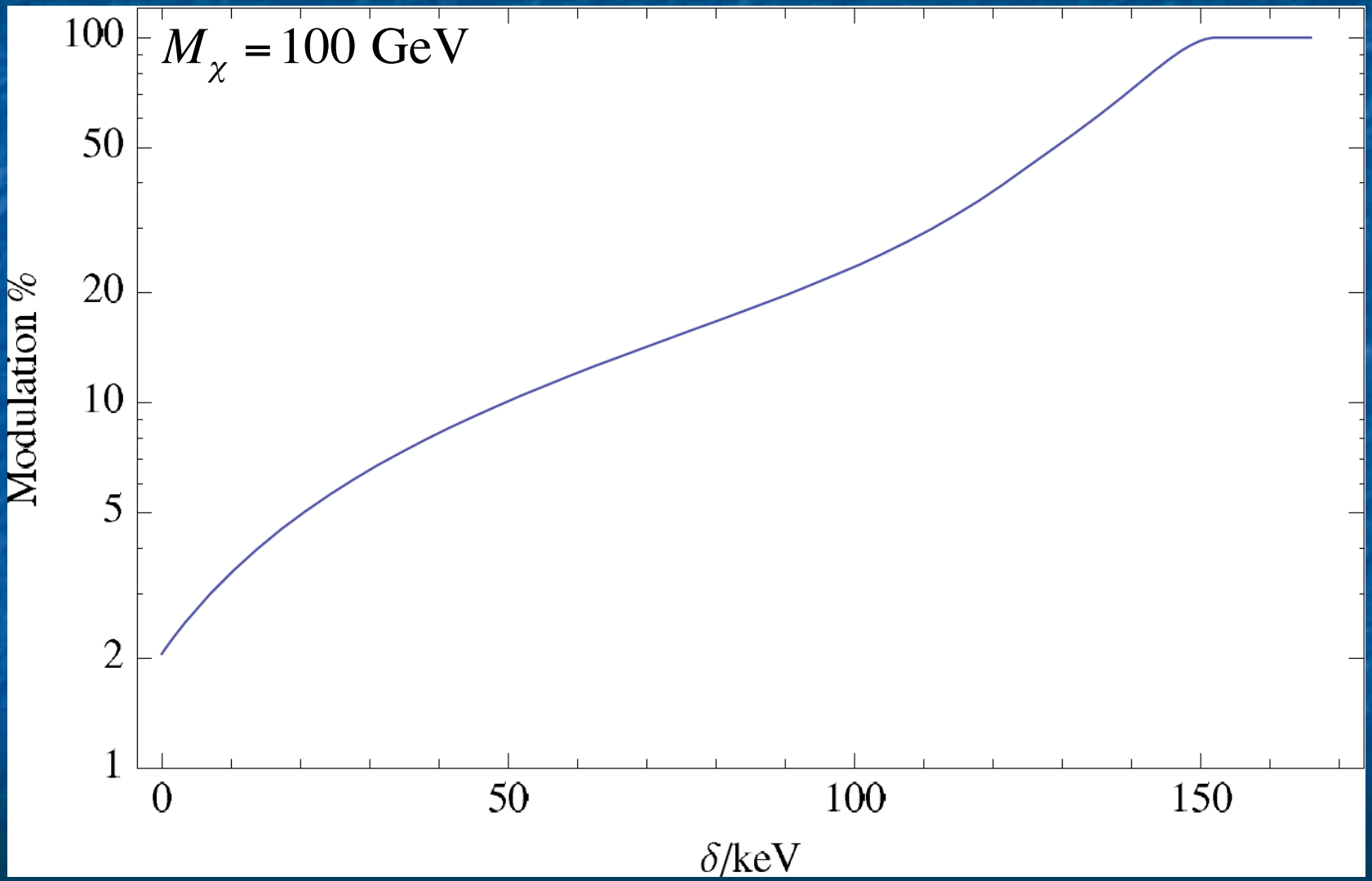
Heavier targets are favored



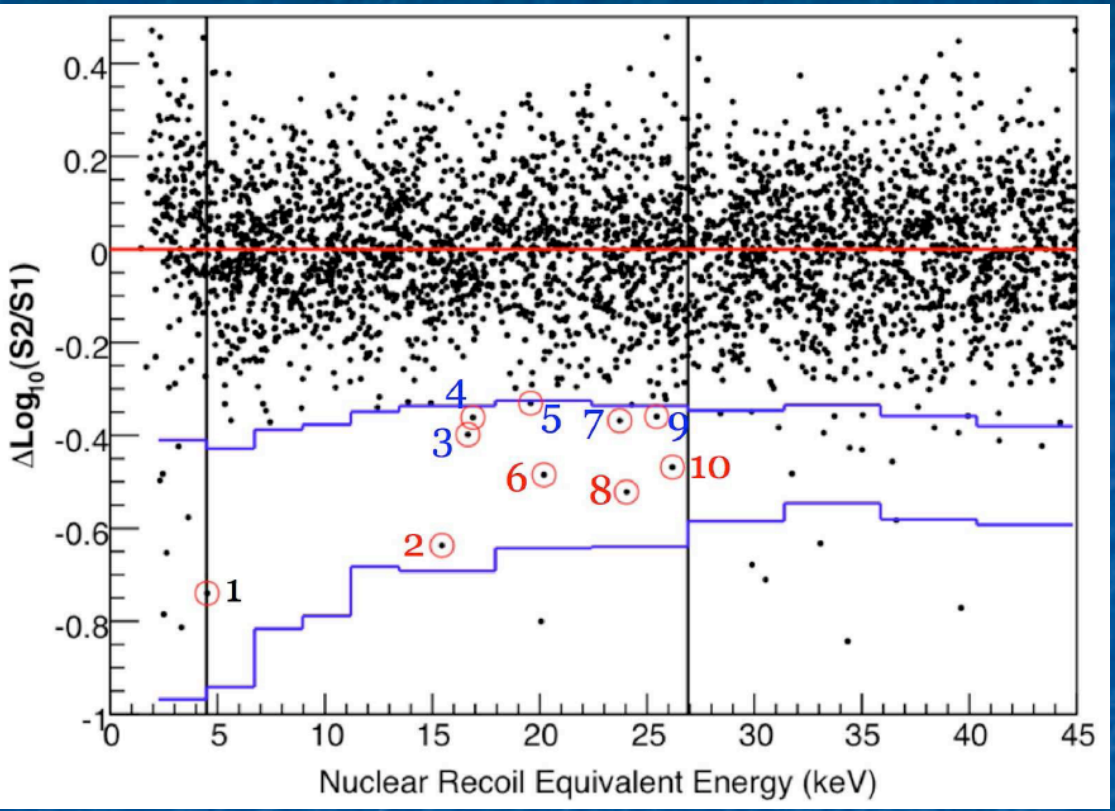
no halo particles have large enough speeds to scatter at CDMS

M.C. Smith et al (2007): v_esc is between 498 km/s and 608 km/s at 90% CL

Annual modulation is enhanced

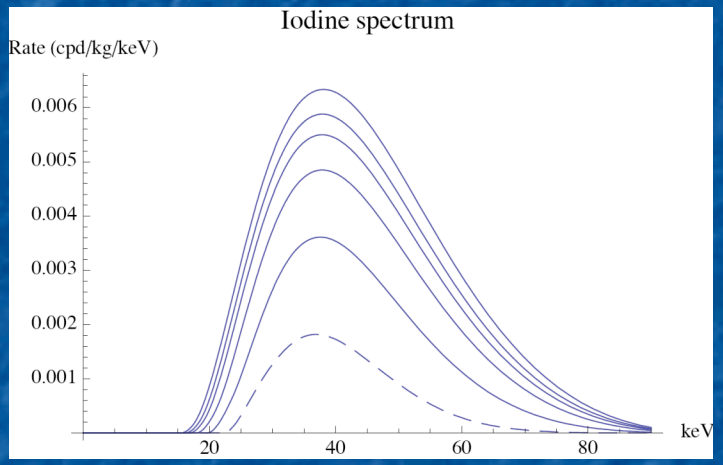


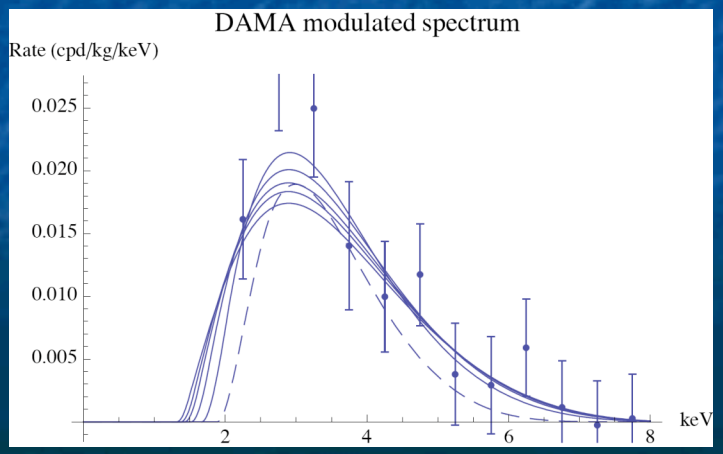
Low energy event rate is suppressed



J. Angle et al. (XENON), Phys.Rev.Lett. 100, 021303 (2008)

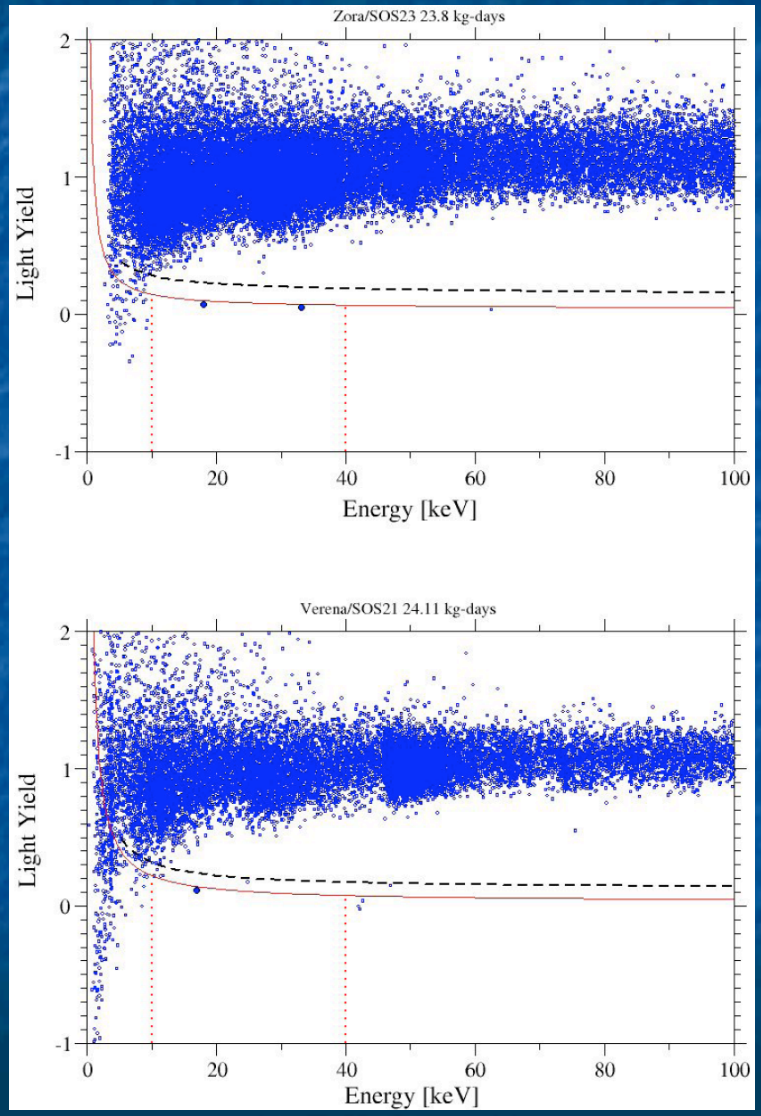
IDM predictions





D. Tucker-Smith, BF2008

Tungsten (A=184): an ideal target



G. Angloher et al. (CRESST), arXiv:0809.1829

about 10 events expected from DAMA signal

D. Tucker-Smith, BF2008

Benchmark Points

#	m_χ (GeV)	σ_n (10^{-40} cm^2)	δ (keV)	DAMA 2-6 keVee (10^{-2} dru)	XENON 4.5-45 keV (counts)	CDMS 10-100 keV (counts)	ZEPLIN 5-20 keVee (counts)	KIMS 3-8 keVee (10^{-2} dru)	CRESST 12-100 keV (counts)
expt				1.31 ± 0.16	24 (31.6)	2 (5.3)	29 (37.2)	5.65 ± 3.27	7 (11.8)
1	70	11.85	119	0.89	1.39	0	8.46	0.65	8.76
2	90	5.75	123	1.21	5.52	0	14.40	1.52	9.75
3	120	3.63	125	1.22	9.06	0.13	18.09	2.18	10.7
4	150	2.92	126	1.18	11.17	0.95	19.93	2.53	11.2
5	180	2.67	126	1.15	12.46	1.93	21.01	2.74	11.6
6	250	2.62	127	1.11	14.01	3.60	23.32	3.00	12.1

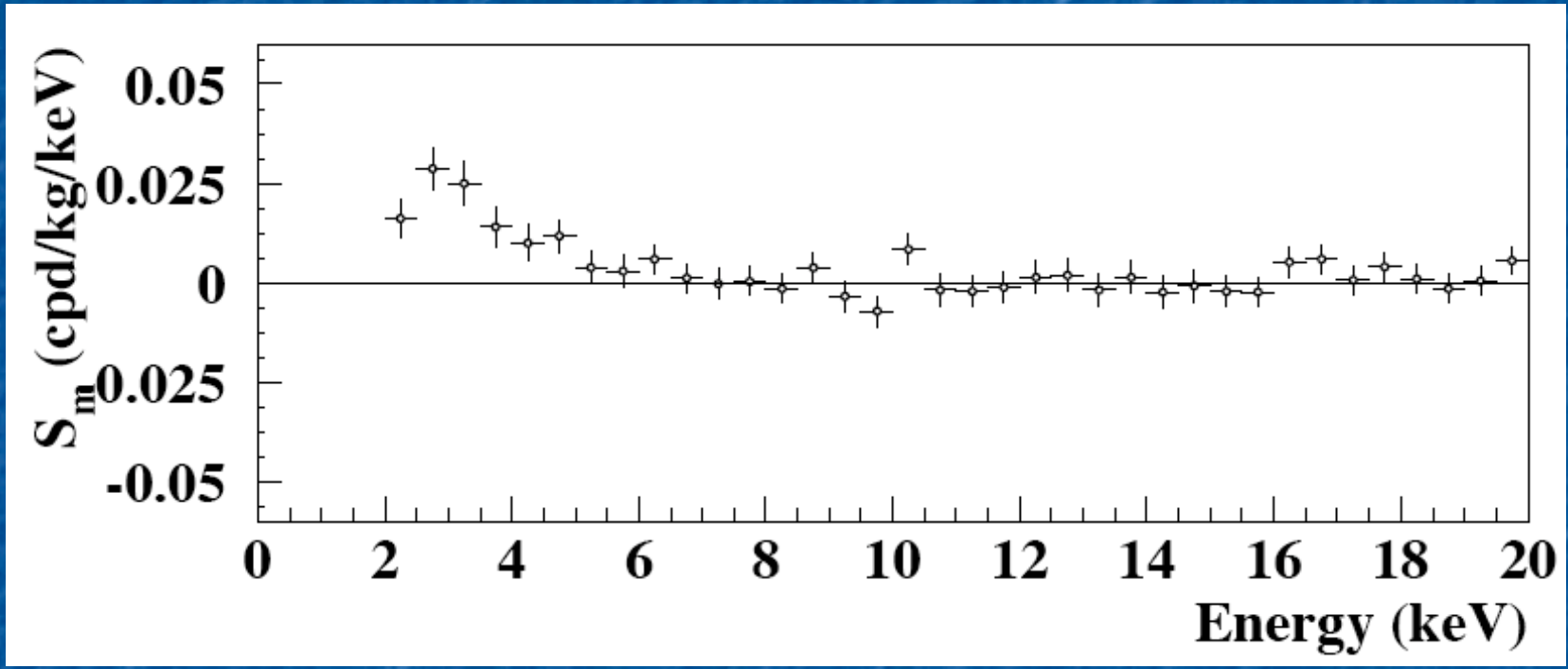
Analysis details

- 3 dof (m, σ, δ) fit to DAMA spectral modulation data.

- For other experiments, reported events are counted as potential signal events when obtaining bounds.

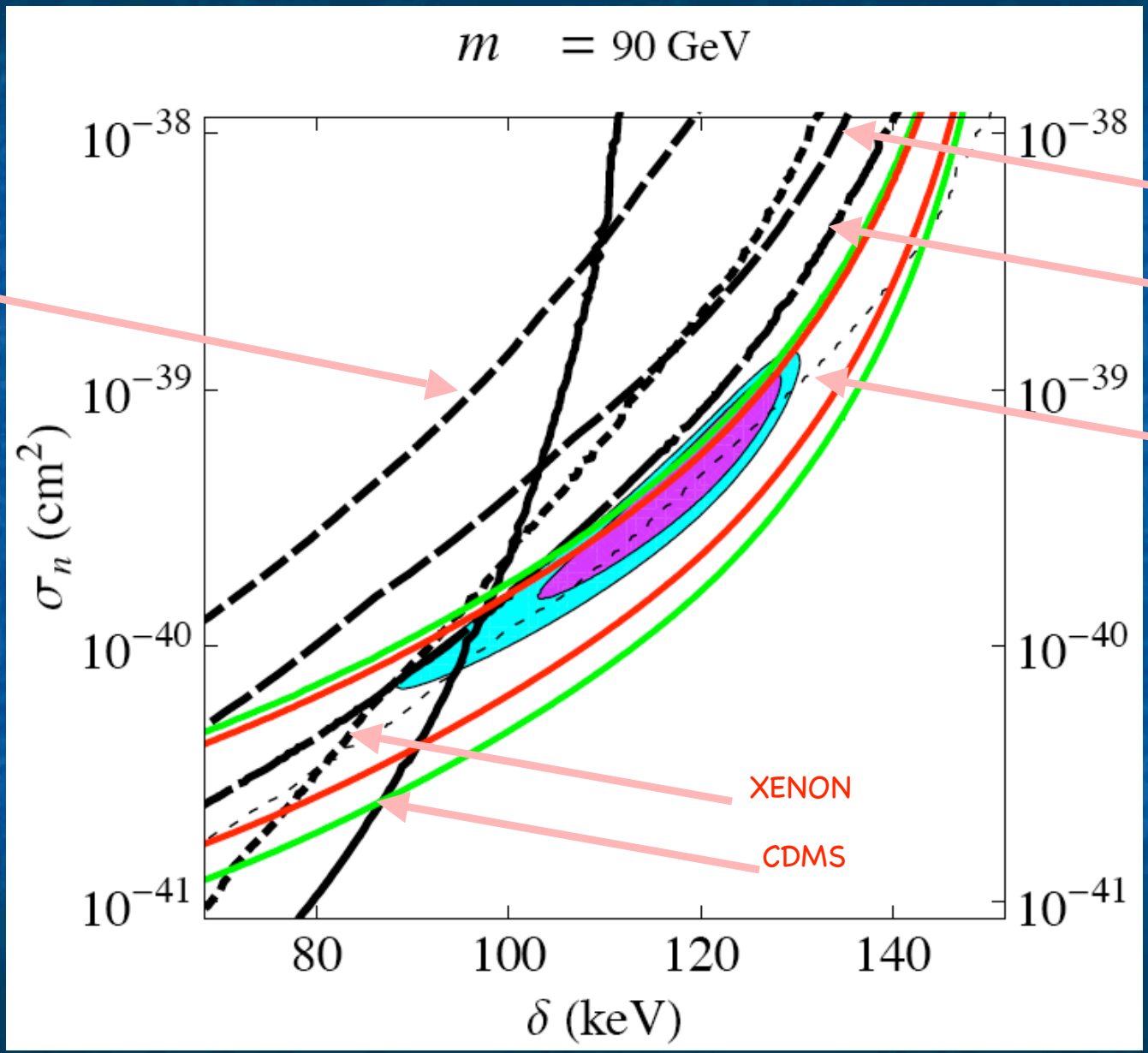
- Used pmax method to obtain 90%CL bounds.

Yellin



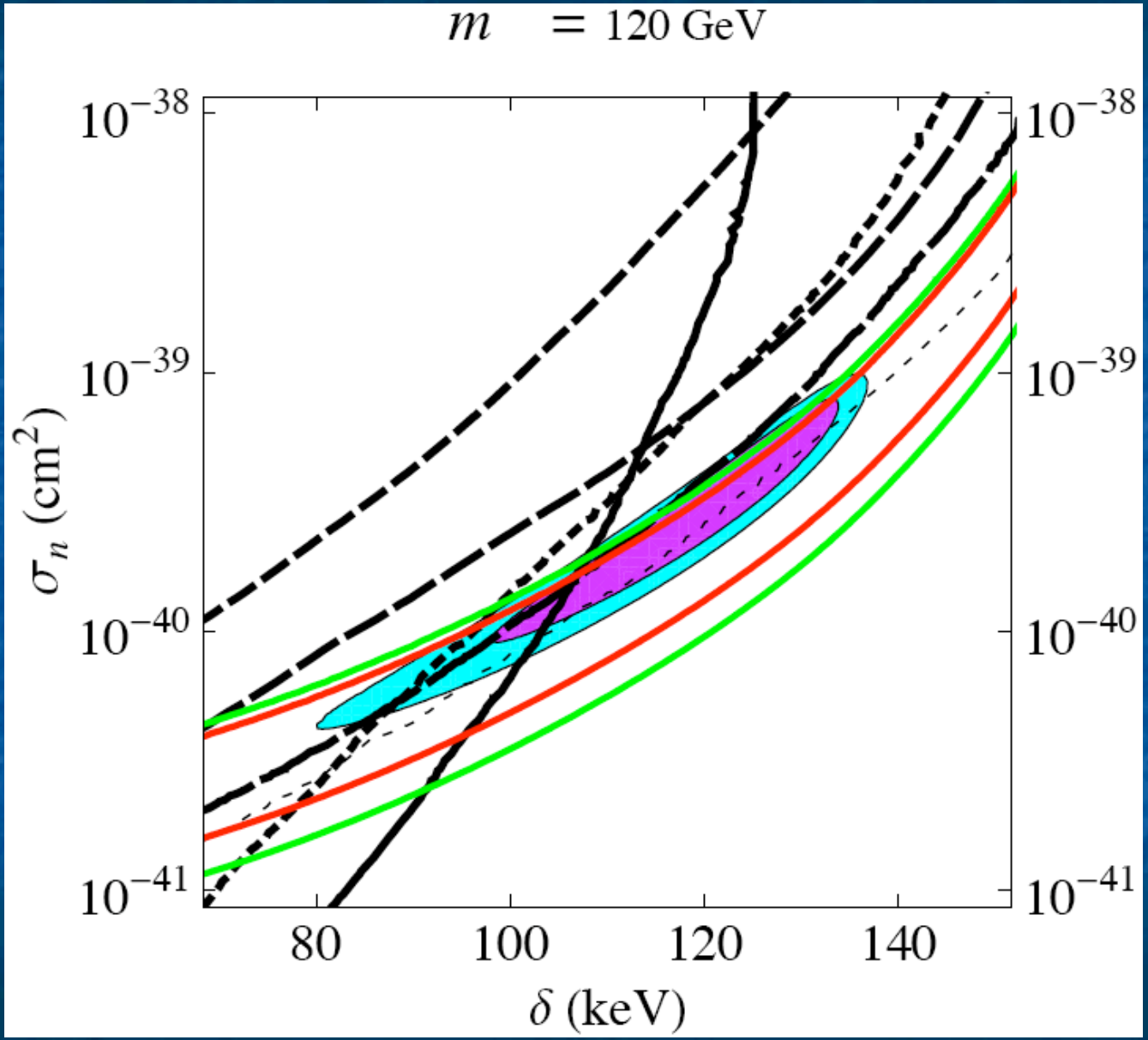
DAMA Collaboration (R. Bernabei *et al.*), **Eur.Phys.J.C56:333-355,2008**.

Parameter space: δ – σ



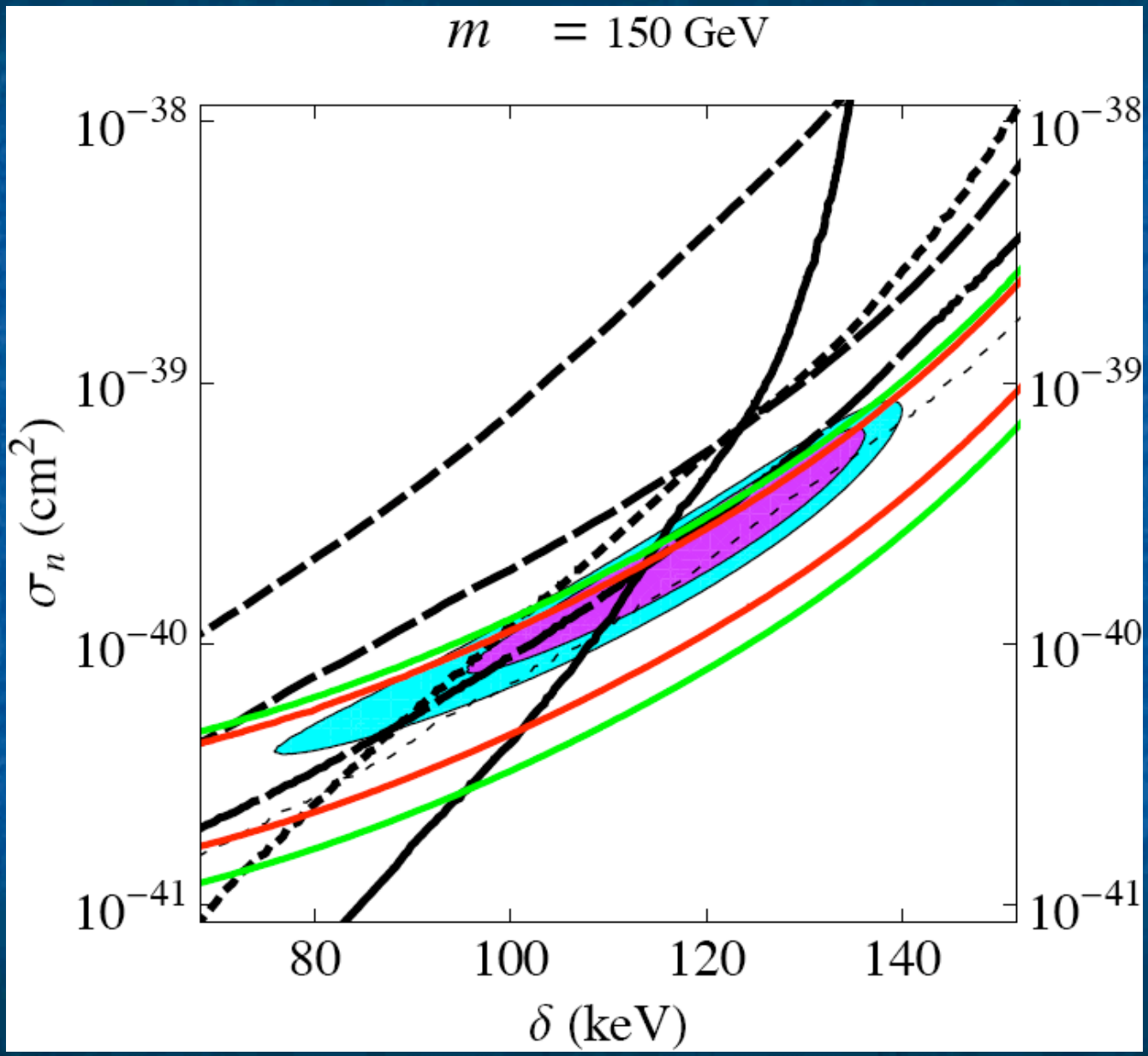
D. Tucker-Smith, BF2008

Parameter space: $\delta - \sigma$



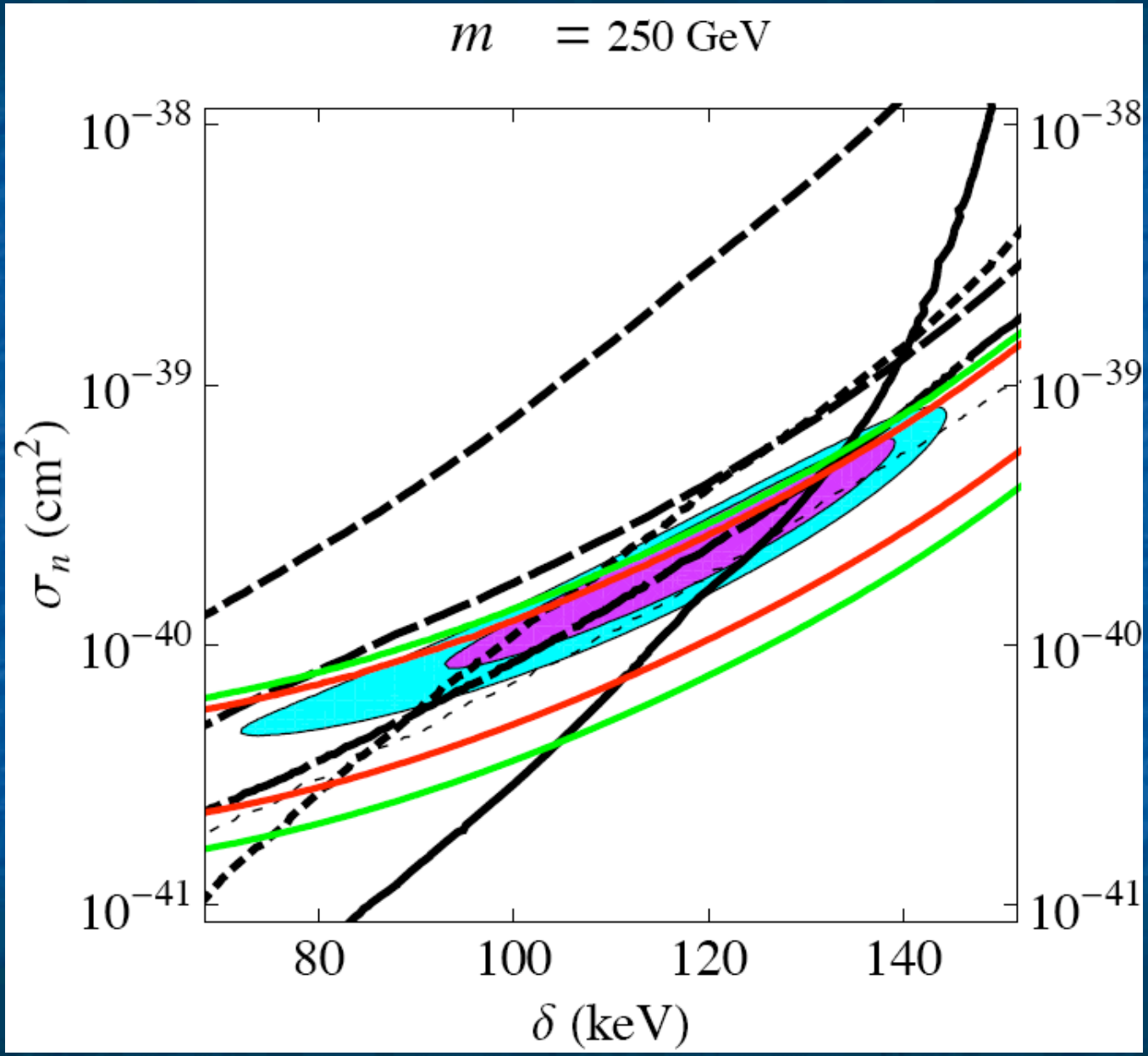
D. Tucker-Smith, BF2008

Parameter space: $\delta - \sigma$



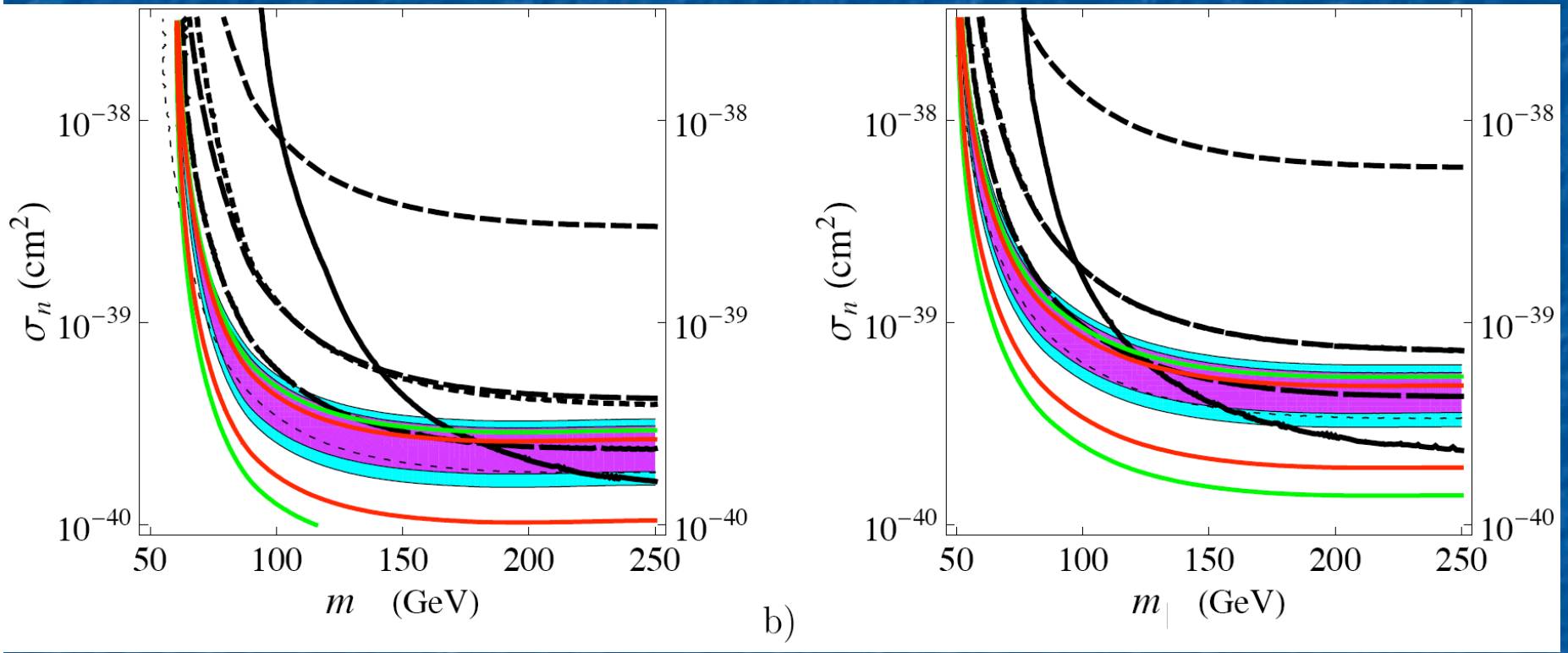
D. Tucker-Smith, BF2008

Parameter space: $\delta - \sigma$



D. Tucker-Smith, BF2008

Parameter space: $m - \sigma$



v_{esc} = 500 km/s

v_{esc} = 600 km/s

Conclusions

- The inelastic dark matter hypothesis is still consistent with all direct-detection experiments.
- Scenario prefers heavy targets, leads to enhanced annual modulation, and predicts very different energy spectra (suppressed at low energies).
- This scenario will soon be ruled out or confirmed (next results from CRESST may be decisive).